From: Robert Rule (Bob@demaximis.com)
Sent: Tue 12/9/2008 05:19 PM
Rcvd: Tue 12/9/2008 05:27 PM
To: Terese VanDonsel (vandonsel.terese@epa.gov); Regan Williams (regan.williams@epa.state.oh.us)
CC: Wayne Reiber (Wayne_Reiber@Cabot-Corp.com); Rick Mason (rmason@rtiintl.com); Ralph E. Cascarilla
Subject: DNAPL Memo

==

Terese & Sig,

Attached is an analysis of the DNAPL in the north sewer, Detrex interceptor trench and DS Trib. As I indicated last week, FBAG has obtained some additional samples in the DS Trib at State Road. In addition, the document contains the calculations regarding the DNAPL flux into the Detrex cutoff trenches, as you requested. We can discuss further during our meeting on Friday.
If you have questions, please contact me.

Bob

Memorandum

Gradient
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To: FBAG Technical Committee **Date:** December 9, 2008

From: Manu Sharma

Subject: Detrex DNAPL Analysis

The FBAG Technical Committee asked that we present and analyze data that have been collected at the Detrex groundwater interceptor trench (southern edge of Detrex property), the North Sewer, and the DS Tributary (western edge of Detrex property) to assess whether DNAPL is continuing to migrate from the former Detrex Lagoons. We understand that USEPA has requested FBAG to provide them with the calculations, analysis and underlying data that underscores FBAG's assertion that Detrex DNAPL is not confined to the northeast and north central portion of the Detrex facility, is present at multiple locations adjacent to the facility, and is moving towards and entering Fields Brook. In particular, the analysis results demonstrate the following:

1. Detrex DNAPL is migrating into the Detrex groundwater interceptor – material that was migrating into the EU8 portion of Fields Brook prior to trench installation in January 2007 (to the south);
2. DNAPL has migrated beyond the Detrex slurry wall and is manifesting itself at the DS tributary (to the west); and
3. DNAPL has migrated beyond the western boundary of the Detrex facility and is manifesting itself along the North Sewer and eventually entering Fields Brook in EU6 (to the southwest).

In summary, source control measures undertaken at Detrex have been inadequate, as evident from the data and findings presented in the remainder of this memorandum.

Characterization of DNAPL Sites

The guidance document cited below discusses in detail the challenges associated with the characterization and investigation of sites contaminated with DNAPL. "Standard site investigation techniques do not work well to characterize DNAPLs", especially at a Site like this where groundwater is limited and there is no discernible groundwater plume. "Complex and discrete DNAPL migration patterns make it very difficult to delineate subsurface DNAPL using standard investigation techniques. DNAPLs will not be readily apparent in water or soil samples at most sites even if DNAPL is present in the subsurface in significant quantities." Therefore DNAPL presence and distribution needs to be inferred from a lot of data using multiple lines of evidence. "The best method used in DNAPL source area determination may be to use the 'propensity of data' from site characterization efforts. There is no one particular method available to clearly delineate the presence/absence of DNAPL. All data collected during the site investigations and historical site surveys need to be collected and viewed as a whole to determine if there is a potential for DNAPL at the site."[1].

[1] Interstate Technology & Regulatory Council (ITRC), DNAPL Team. 2003. An Introduction to Characterizing Sites Contaminated with DNAPLs. September. Pages 10, 13, 24.

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Although characterization of DNAPL sites can be difficult, the following sections of this memorandum indicate that the data available for the Fields Brook Site, particularly information collected in the last 2 to 3 years, provide multiple lines of evidence that subsurface DNAPL migration from the former Detrex lagoons is continuing and poses a significant threat to Fields Brook.

Detrex Groundwater Interceptor Trench

The groundwater interceptor trench, which is 1400 feet long and consists of three main segments and associated sumps, was installed by Detrex in January 2007 (Figure 1). The objective of the trench was to intercept the southern migration of DNAPL and impacted groundwater from the Detrex lagoon area, where a significant volume of DNAPL is present. The trench is approximately 15 feet in depth and was advanced three feet into the glacial till unit. Groundwater is pumped from the three interceptor trench sumps and then treated (Figure 1). Based on data provided by Detrex, we understand that average groundwater extraction rates at the three sumps (1, 2, and 3, respectively) have been on the order of: 1,250, 750, and 200 gallons per day (gpd) – a total of 2,200 gpd. The water samples collected at the trench sumps indicate the presence of Chlorinated Volatile Organic Compounds (CVOCs), including tetrachloroethene, trichloroethene, 1,2-dichloroethene and 1,1,2,2-tetrachloroethene, at concentrations ranging from 1.1 to 199 µg/L (see Table 1). The detection of these CVOCs is consistent with the composition of the Detrex DNAPL, which has been well characterized and fingerprinted (de maximis, 2005)[2]. As explained in detail below, these flow and concentration data provided by Detrex are highly relevant and indicative of the presence of DNAPL:

- The groundwater extraction rates recorded at the three trench sumps are appreciable for a lacustrine clay system. These relatively high extraction rates would be possible only if there were permeable sand zones in the overburden and lacustrine clay. Such permeable horizons serve as preferential conduits for DNAPL migration in addition to groundwater.
- A comparison of the water quality data collected at the Detrex interceptor trench sumps against data obtained at the North Sewer containment trench sump (a known and significant DNAPL discharge area with visible DNAPL seepage),[3] helps place the interceptor trench data in perspective (see Table 1). CVOC concentrations measured at sump #2 of the interceptor trench are on the same order of magnitude as the North Sewer sump, a DNAPL collection area. The similarity in CVOC concentrations at the interceptor trench and the North Sewer sumps is particularly significant because the interceptor trench is an active system (total withdrawal rate of 2,200 gpd over a 1400 foot trench; sump# 2 – 750 gpd) resulting in significant contaminant dilution, whereas the North Sewer trench is a passive DNAPL collection system (with no groundwater withdrawal). Despite the dilution at the interceptor trench, the similarity in concentrations with the North Sewer sump, indicates that a significant amount of DNAPL is flowing into the interceptor trench (confirmed by calculations results presented below).
- The Detrex groundwater interceptor trench collects all liquids – DNAPL, contaminated groundwater and "clean" groundwater – that are migrating in the subsurface. Groundwater samples collected at eight locations along the interceptor trench prior to its

[2] de maximis, Inc. 2005. Fields Brook Action Group Report of 2005 DNAPL Investigation, Fields Brook Superfund Site, Ashtabula, Ohio. September 30.

[3] Significant DNAPL seeps were observed at the North Sewer area from early 2005 onwards, leading to the installation of a passive subsurface collection trench and sump in 2007 by FBAG.

installation did not encounter any contamination (Figure 2), *i.e.*, a majority of the groundwater flowing into the trench is "clean." This clean groundwater mixes with DNAPL globules and DNAPL-impacted groundwater (which flows in *via* narrow preferential conduits into the trench) and results in the observed groundwater concentrations recorded in the water removed at the sumps. Using the water quality and flow rate data collected at the interceptor trench sumps by Detrex, we performed a mass balance calculation to determine the DNAPL and DNAPL-impacted groundwater flow rate entering each segment of the Detrex trench (Attachment A). The mass balance results indicated that up to 2,682 gallons per year of a DNAPL-groundwater mixture, *i.e.*, DNAPL globules/ganglia and groundwater in contact with DNAPL, is flowing into the Detrex trench (Attachment A). The DNAPL flux was highest in trench segment #2, which is consistent with segment #2 being located directly downgradient of the Detrex lagoon area. These results further demonstrate that the Detrex trench is currently intercepting DNAPL, which prior to the installation of this system, was migrating to the brook.

Overall, the groundwater extraction rate and the water quality measured at the Detrex interceptor trench, together with the mass balance analysis results clearly indicate that DNAPL at the Detrex source area continues to feed subsurface migration pathways towards the southern edge of the property.

DNAPL Migration Beyond the Slurry Wall

The following data collected at the DS Tributary indicate that DNAPL has migrated beyond the Detrex slurry wall along the western property boundary.

- DNAPL globules are visible in surficial sediments and a strong odor (characteristics of Detrex DNAPL) is present in the DS Tributary, immediately to the west of State Road. This visual presence of DNAPL was not observable in 2001 or in prior years. Sediment samples collected in the DS Tributary in November 2008 confirm that DNAPL has affected sediment quality since elevated concentrations of CVOCs and other Detrex marker compounds (*e.g.*, hexachlorobenzene and hexachlorobutadiene) were detected (Figures 3 and 4). Furthermore, exceedances of the sediment remedial action levels are now being observed in this area, whereas no exceedances were previously observed and no remediation was necessary (Figure 3).
- Soil and groundwater samples collected near the DS Tributary present strong evidence that Detrex DNAPL is also located in the subsurface in this area.
  - A groundwater sample collected at DPT-10 (8 to 10 ft-bgs) detected extremely high concentrations of the four primary CVOCs: tetrachloroethene (6,580 µg/L), trichloroethene (62,900 µg/L), 1,2-dichloroethene (1,690 µg/L) and 1,1,2,2-tetrachloroethene (11,600 µg/L) – ranging from 1% to approximately 50% of their calculated effective solubility limits (Table 3). According to (USEPA, 1992)[4], the presence of a component of a DNAPL mixture in groundwater at a concentration greater than 1% of its effective solubility, typically indicates the presence of DNAPL. Therefore, the detection of CVOCs at levels up to 50% of their effective solubility limits is very strong evidence that DNAPL is present in the subsurface near the DS Tributary.

[4] US EPA. 1992. Estimating Potential for Occurrence of DNAPL at Superfund Sites. January.

- In addition, the soil sample collected at DPT-10 (8 to 10 ft-bgs) also detected elevated CVOC concentrations (277 mg/kg) that are indicative of DNAPL (Figure 4). For example, the trichloroethene and tetrachloroethene concentrations detected at DPT-10 exceed the threshold soil concentration (C_{sat}) above which NAPL is expected to be present (USEPA, 1996)[5] (Table 2).

Overall, the soil and groundwater quality data collected at DPT-10 clearly demonstrate that this soil boring intercepted a DNAPL pool or ganglion – a rare occurrence when using conventional investigation methods, such as drilling, unless DNAPL presence is widespread. Note, CVOCs were also detected in the subsurface at other locations along State Road, just south of the DS Tributary (Figure 4). Given the proximity of these locations to the DS Tributary DNAPL seepage area and DPT-10 (and the North Sewer DNAPL seepage), these concentrations may be reflective of additional DNAPL migration pathways towards the south (Figure 4).

To summarize, the presence of DNAPL seepage at the DS Tributary, exceedances of sediment remedial action levels in the DS Tributary (none were previously present and no remediation was required in this area), and the presence of elevated subsurface soil and groundwater concentrations indicative of DNAPL near the DS Tributary clearly demonstrate that Detrex DNAPL has migrated beyond the Detrex slurry wall and is manifesting itself at the DS tributary.

DNAPL Manifestation at the North Sewer

The following data collected at and in the vicinity of the North Sewer also indicates that DNAPL from the Detrex property has migrated beyond the western property boundary:

- DNAPL seepage was clearly visible at the North Sewer outfall from 2005 until 2007, when FBAG installed a passive DNAPL subsurface collection trench. The extended period of seepage indicates that the seeps were being fed by a significant DNAPL source indicating the inadequacy of the slurry wall as a source control measure.
- During the North Sewer investigation performed by Detrex in 2006/2007, hexachlorobenzene was detected in sediment samples collected at the North Sewer outfall at concentrations up to 696 mg/kg, which exceeds the remedial action level for hexachlorobenzene (45 mg/kg: Figure 3).
- Elevated concentrations of total CVOCs were also detected in soil samples collected in the vicinity of the North Sewer (*e.g.*, 107 mg/kg at TP6 and 432.5 mg/kg at NSTB-5B and 58.7 mg/kg at NSTB-7) (Figure 4). A comparison of these soil concentrations against C_{sat} values indicates that the cis-1,2-dichloroethene, trichloroethene and tetrachloroethene C_{sat} values were exceeded in samples collected at TP6 (under sewer pipe), NSTB-5B (12 to 14 ft-bgs) and NSTB-7 (10 – 12 ft-bgs) (Table 2), *i.e.,* DNAPL is present in these samples, which are located north of the Fields Brook floodplain in EU6.
- In June 2008, high CVOC concentrations, (up to 1,195 mg/kg), were found in subsurface soils south of Fields Brook just west of State Road in EU6, on top of the lacustrine clay deposits, *i.e.*, approximately 8 to 10 feet below ground surface (bgs) (Figure 4). These elevated soil concentrations, which exceeded C_{sat} values for VOCs at seven locations (Table 2), are also indication that Detrex DNAPL has migrated along the top of the clay surface and accumulated in this area, a natural low spot in the clay's surface.

[5] United States Environmental Protection Agency (USEPA). 1996. Soil Screening Guidance: Technical Document. May.

- Geoprobes advanced near the northern State Road Bridge pier prior to brook remediation in 2001 and field observations during the remediation indicate that DNAPL has accumulated at this bridge pier in the upland area (*i.e.*, not in the floodplain area) (Figure 5).

  It is important to note that all DNAPL related findings near the North Sewer (C_{sat} exceedances at NSTB-5, NSTB-7, area south of the brook, visual observations in Geoprobes along cross-section G-G') were found approximately 8 to 14 ft-bgs, which generally corresponds to the top of the lacustrine clay layer. This clearly indicates subsurface DNAPL migration along the top of the lacustrine clay layer (and via sand lenses within the clay) – a conclusion that also applies to the DS Tributary area (elevated soil and groundwater concentrations at DPT-10 are at 8 to 10 ft-bgs) and in the area south of the former Detrex lagoons (the Detrex groundwater interceptor trench).

Overall, the data in the vicinity of the North Sewer clearly indicate that Detrex DNAPL has migrated beyond their western property boundary and is manifesting at the North Sewer. Although Detrex needs to collect additional data to define the exact pathway by which the DNAPL is reaching the North Sewer, it is important to note that there is about a 1000 foot gap between the Detrex slurry wall and Detrex groundwater interceptor trench along their western property boundary (Figure 3 and 4).

Table 1
Summary of Detrex Groundwater Interceptor Trench and North Sewer Sump Data
Fields Brook Superfund Site

Detrex Groundwater Interceptor Trench Data

Sump #1 - 1250 gpd

Compound (μg/L)	Date				Average Concentration (μg/L)
	9/21/2007	11/26/2007	1/3/2008	2/8/2008	
1,1,2,2-Tetrachloroethane	0	0	0	0	-
cis-1,2-Dichloroethylene	0	0	0	0	-
Tetrachloroethylene	5.85	0	1.96	1.13	2.2
Trichloroethylene	7.22	0	2.8	1.57	2.9

Sump #2 - 750 gpd

Compound (μg/L)	Date				Average Concentration (μg/L)
	9/21/2007	11/26/2007	1/3/2008	2/8/2008	
1,1,2,2-Tetrachloroethane	3.45	0	0	1.81	1.3
cis-1,2-Dichloroethylene	199	58	92.8	88.7	109.6
Tetrachloroethylene	25.1	0	0	3.65	7.2
Trichloroethylene	72.1	17.8	21.3	26.6	34.5

Sump #3 - 200 gpd

Compound (μg/L)	Date				Average Concentration (μg/L)
	9/21/2007	11/26/2007	1/3/2008	2/8/2008	
1,1,2,2-Tetrachloroethane	0	0	0	0	-
cis-1,2-Dichloroethylene	0	0	0	0	-
Tetrachloroethylene	0	0	1.28	1.08	0.6
Trichloroethylene	0	0	1.53	1.5	0.8

North Sewer Sump Data - 0 gpd

Compound (μg/L)	Date				Average Concentration (μg/L)
	9/28/2007	11/26/2007	2/15/2008	5/1/2008	
1,1,2,2-Tetrachloroethane	167	0	0	0	41.8
1,1,2-Trichloroethane	18.6	0	0	0	4.7
Chloroform	1.86	0	0	0	0.5
cis-1,2-Dichloroethylene	NA	44.8	65.2	115	75.0
Tetrachloroethylene	NA	49.5	33.8	19.9	34.4
Trichloroethylene	2520	124	95.8	77.8	704.4

Note:

- Assumed a concentration of zero in the case of non-detections.

Table 2
Soil Saturation Concentration Calculation and List of Exceedances
Fields Brook Superfund Site, Ashtabula, OH

Compound	Effective Solubility (S)[1] mg/L	Organic Carbon Partition Coefficient (Koc)[2] L/kg	Soil Water Partition Coefficient (Kd) L/kg	Henry's Law Constant (H')[2] Unitless	Soil Saturation Concentration (C_{sat})[3] mg/kg	Sample Locations with C_{sat} Exceedances
Cis-1,2-Dichloroethene	11.2	43.8	0.0876	0.167	2.29	TP6 (3.6 mg/kg), MLSS-02 (3.3 mg/kg), MLSS-04 (30 mg/kg), MLSS-14 (6.3 mg/kg), MLSS-15 (4.7 mg/kg)
Trichloroethene	673.3	67.7	0.14	0.403	185.63	NSTB-5B (257 mg/kg), MLSS-15 (600 mg/kg), DPT-10 (252 mg/kg)
Tetrachloroethene	13.3	107	0.214	0.724	5.14	NSTB-5B (175 mg/kg), TP6 (83.3 mg/kg), NSTB-7 (42.3 mg/kg), MLSS-9 (84 mg/kg), MLSS-10 (36 mg/kg), MLSS-13 (18 mg/kg), MLSS-14 (9.6 mg/kg), MLSS-15 (590 mg/kg), DPT-10 (24.7 mg/kg)
1,1,2,2-Tetrachloroethane	1059.6	107	0.214	0.015	334.30	--

Fraction of organic carbon (foc)	0.002	
Bulk Density (ρ)	1.50	g/ml
Water-filled Porosity (θw)	0.15	
Air-filled Porosity (θa)	0.15	

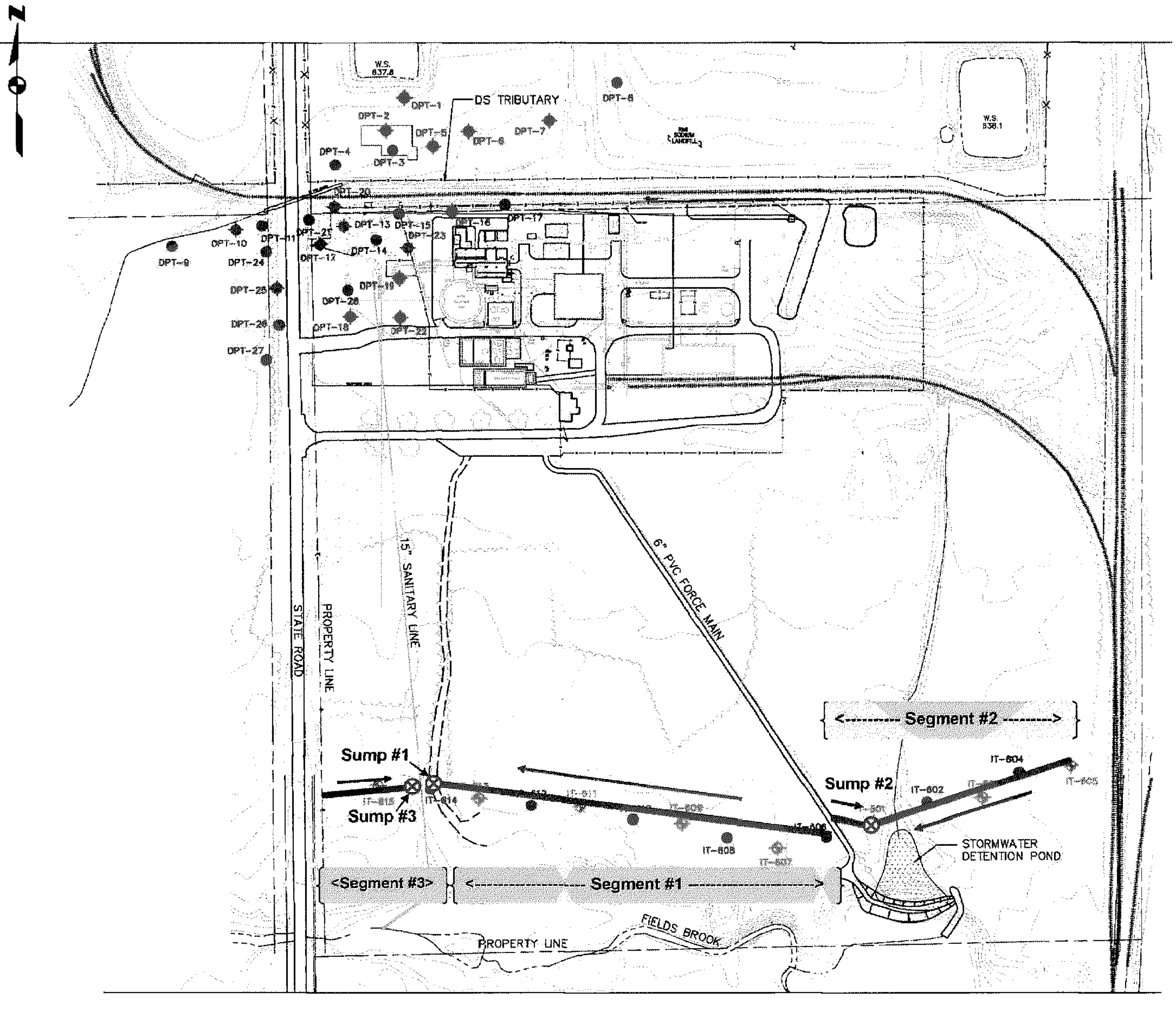
$Csat = (S/\rho) * (Kd * \rho + \theta w + H' * \theta a)$

Source:
1) Effective solubility calculations are presented in Attachment A.
2) Risk Assessment Information System: http://rais.ornl.gov
3) United States Environmental Protection Agency (USEPA). 1996. Soil Screening Guidance: Technical Document. May.

Table 3
Comparison of CVOC Detections in DPT-10 Groundwater and Effective Solubility

Compound	Concentration in Groundwater (μg/L)	Effective Solubility (μg/L)[1]	Ratio of Groundwater Concentration to Effective Solubility
1,2-Dichloroethene	1,690	11,200	0.2
Trichloroethene	62,900	673,300	0.1
Tetrachloroethene	6,580	13,300	0.5
1,1,2-Trichloroethane	1,610	300	5.4
1,1,2,2-Tetrachloroethane	11,600	1,059,600	0.01

Note:
1) Effective solubility calculations are presented in Attachment A.



LEGEND

- TEMPORARY WELL (2-INCH)
- TEMPORARY PIEZOMETER (1-INCH)
- BORING

Groundwater Interceptor Trench Construction & Installation Report

Figure 2
GWIT Preliminary Alignment

Detrex Corporation
Ashtabula Facility
Ashtabula, OH

URS

August 2007

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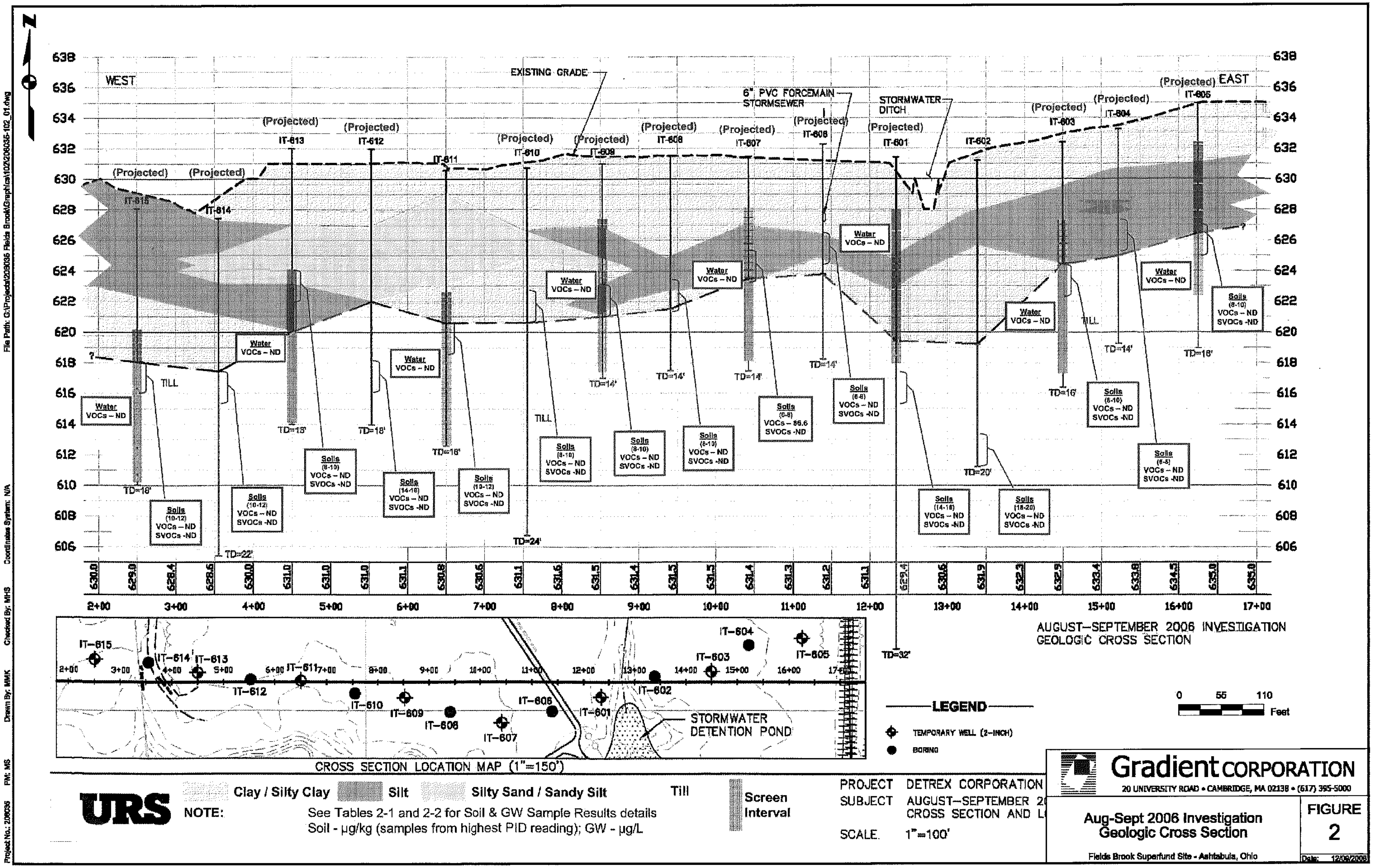
Detrex Groundwater Interceptor Trench

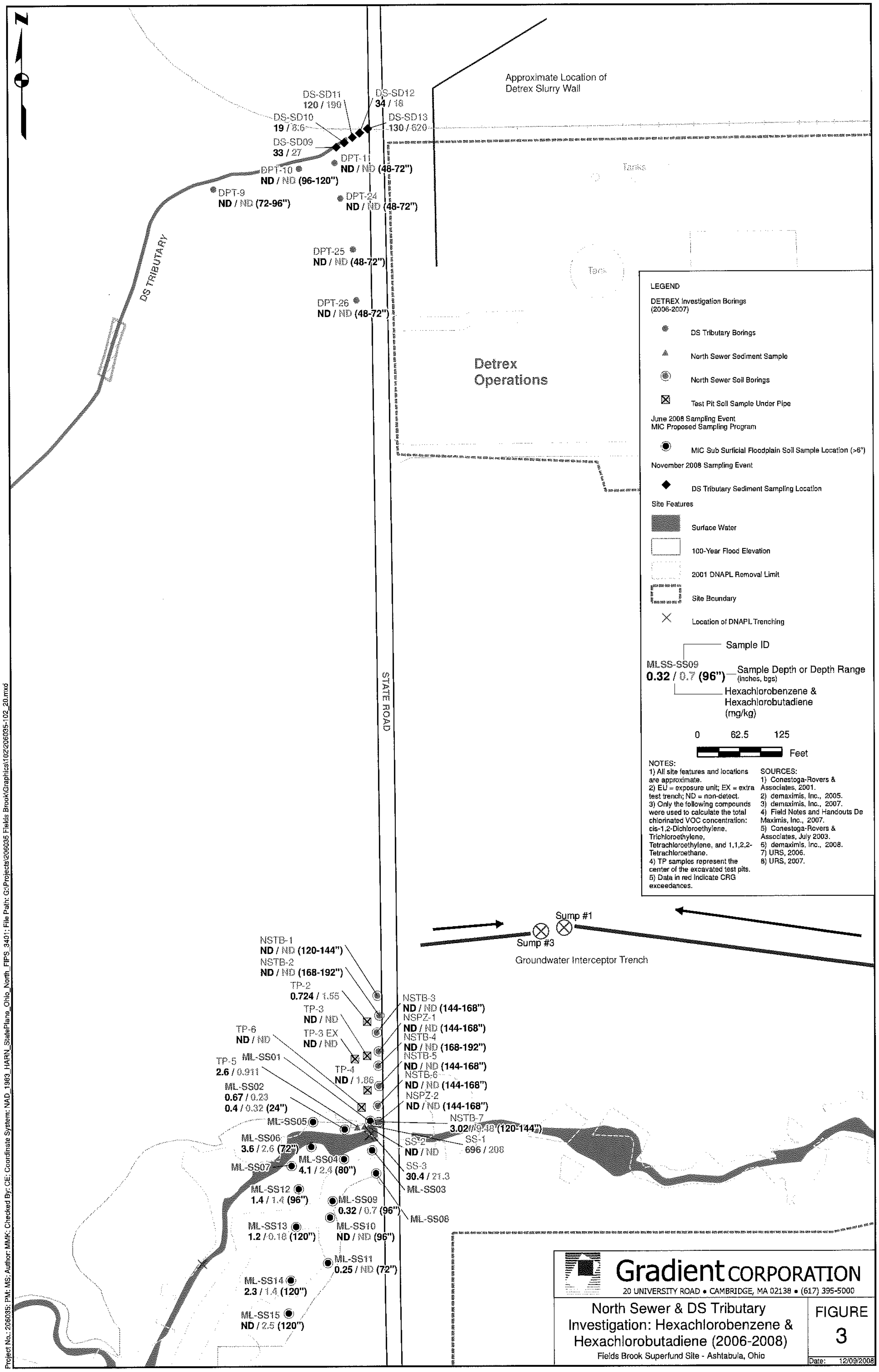
Fields Brook Superfund Site - Ashtabula, Ohio

FIGURE 1

Date: 12/09/2008

Project No.: 206035 PM: MB Drawn By: MMK Checked By: MHB Coordinates System: N/A File Path: G:\Projects\206035 Fields Brook\Graphics\102\206035-102_01.dwg


WEST
EAST
EXISTING GRADE
6" PVC FORCEMAIN
STORMSEWER
STORMWATER DITCH
TILL
Water VOCs – ND
Soils VOCs – ND SVOCs -ND
AUGUST–SEPTEMBER 2006 INVESTIGATION GEOLOGIC CROSS SECTION
CROSS SECTION LOCATION MAP (1"=150')
STORMWATER DETENTION POND
LEGEND
TEMPORARY WELL (2-INCH)
BORING
0 55 110 Feet
Clay / Silty Clay
Silt
Silty Sand / Sandy Silt
Till
Screen Interval
URS
NOTE:
See Tables 2-1 and 2-2 for Soil & GW Sample Results details
Soil - µg/kg (samples from highest PID reading); GW - µg/L
PROJECT DETREX CORPORATION
SUBJECT AUGUST–SEPTEMBER 2
CROSS SECTION AND L
SCALE 1"=100'
Gradient CORPORATION
20 UNIVERSITY ROAD • CAMBRIDGE, MA 02138 • (617) 395-5000
Aug-Sept 2006 Investigation Geologic Cross Section
Fields Brook Superfund Site - Ashtabula, Ohio
FIGURE 2
Date: 12/09/2008
File Path: G:\Projects\208036 Fields Brook\Graphics\102\208036-102_01.dwg
Coordinates System: N/A
Checked By: MHS
Drawn By: MMK
PM: MS
Project No.: 208036



North Sewer & DS Tributary Investigation: Hexachlorobenzene & Hexachlorobutadiene (2006-2008)

Fields Brook Superfund Site - Ashtabula, Ohio

Project No.: 206035; PM: MS; Author: MMK; Checked By: CE; Coordinate System: NAD_1983_HARN_StatePlane_Ohio_North_FIPS_3401; File Path: G:\Projects\206035 Fields Brook\Graphics\102\206035-102_20.mxd

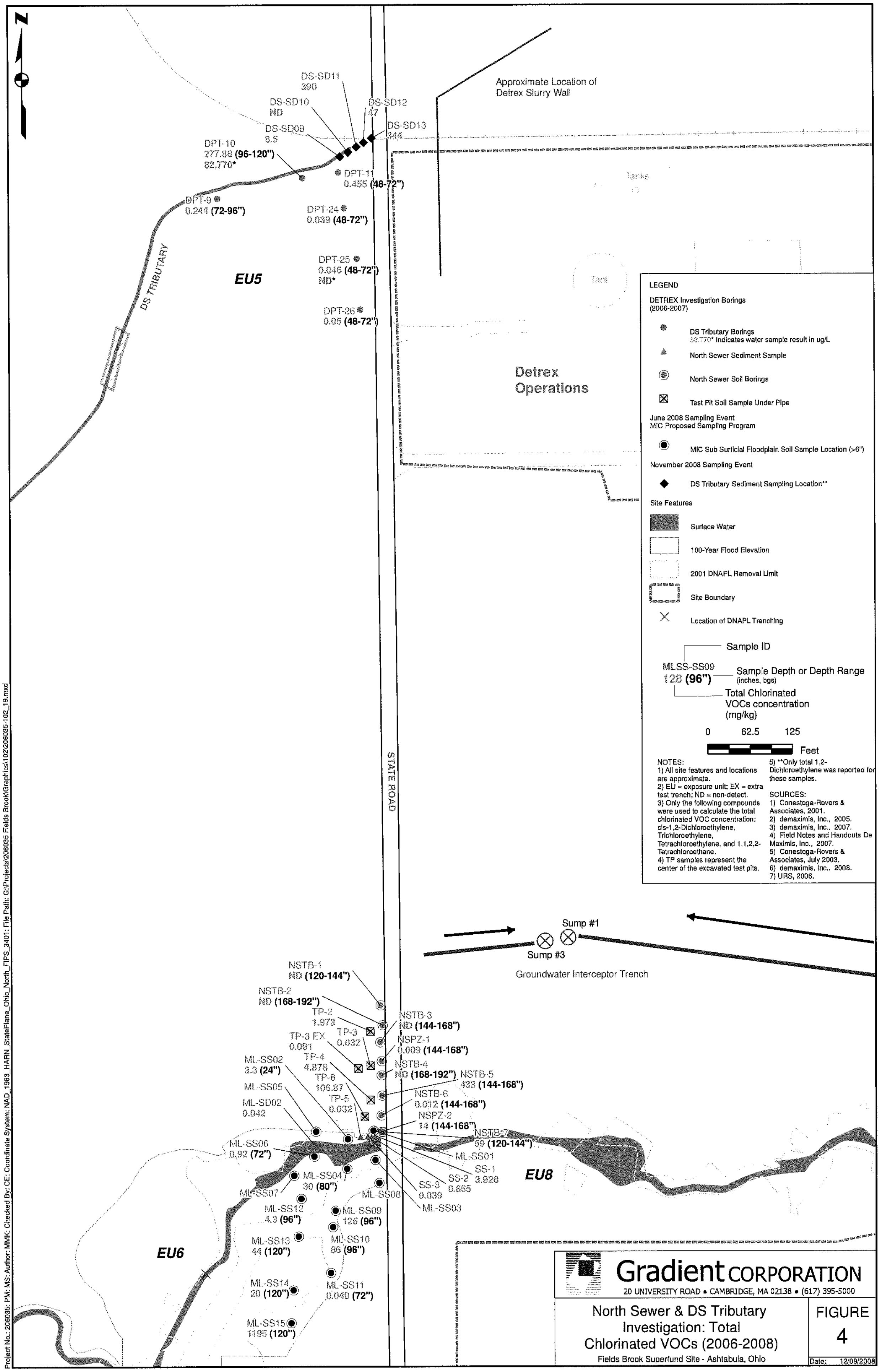
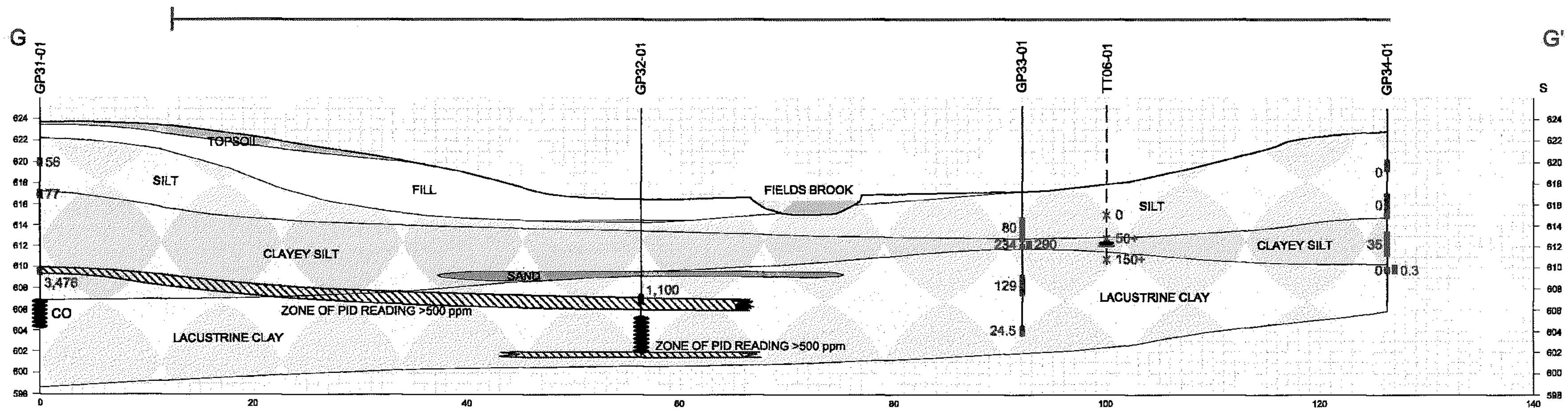


FIGURE 4

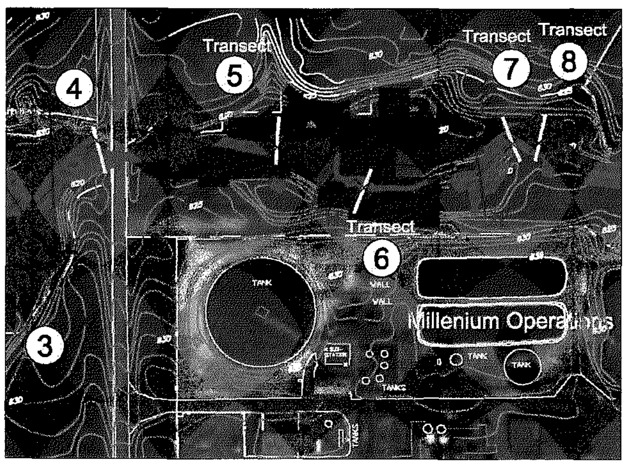
North Sewer & DS Tributary Investigation: Total Chlorinated VOCs (2006-2008)

Fields Brook Superfund Site - Ashtabula, Ohio



CROSS-SECTION G-G'

10' 0 10'
HORIZONTAL & VERTICAL SCALE



0 100 200 Feet

LEGEND:

100-Year Floodplain

Borehole ID

PID Reading measured during 2001 Investigation (ppm)

Sample Interval

Total Chlorinated Ethenes (mg/kg)

Projected Test Pit /Trench on Cross-section PID Reading measured during 2001 Investigation (ppm)

DNAPL observed in 2001

Silt/Lacustrine Clay interface projected from test pit/trench located outside of the cross-section plane.

Zone of PID readings greater than 500 ppm defined by CRA using Geoprobe data; do not reflect test pit/trench PID and soil analytical data that were added by Gradient to the cross-section.

Stratigraphy

- Top Soil
- Fill
- Sand/Silty Sand
- Silt
- Clayey Silt
- Lacustrine Clay

NOTE:
1) Stratigraphy is based on March 2001 DNAPL Investigation cross-sections. (Appendix G, July 2003 Final Construction report).

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Cross-Section G-G'
Showing DNAPL Locations in 2001

Fields Brook Superfund Site - Ashtabula, Ohio

FIGURE 5

Date: 12/09/2008

Project No.: 206035 PM: MS Drawn By: MMK Checked By: MHS Coordinates System: N/A File Path: G:\Projects\206035 Fields Brook\Graphics\1023\206035-102_03.dwg

Attachment A
Detrex Groundwater Interceptor Trench Calculations

This attachment describes the calculations performed to determine the nature and volume of contamination recovered by the Detrex groundwater interceptor trench, using available water quality and flow data, and the following assumptions:

- The groundwater flux into the trench is a combination of DNAPL-groundwater mixture, (*i.e.*, DNAPL globules and groundwater in contact with DNAPL) and "clean" groundwater (*i.e.*, groundwater that has not been in contact with the DNAPL.
- The maximum concentration of a contaminant in the DNAPL-impacted groundwater is equal to the effective solubility of that contaminant in water. Given that the Detrex DNAPL is a mixture of a dozen organic compounds, Raoult's Law dictates that the effective solubility of each contaminant in groundwater that has been in contact with the DNAPL is proportional to the mole fraction of that contaminant in the mixture.
- No contaminants were detected in the "clean" groundwater. This assumption is reasonable, given the absence of VOCs in the groundwater samples collected along the length of the trench prior to its installation (see Figure 2).

In order to determine the flux of DNAPL-groundwater mixture into each segment of the trench, we used a simple mass balance approach represented by the following equation:

$$(V_{W-DNAPL} \times C_{W-DNAPL}) + (C_{gw} \times V_{gw}) = (C_{Sump} \times V_{Total})$$

Where:

$V_{W\text{-}DNAPL}$ = Average flux of DNAPL-groundwater mixture (*i.e.*, DNAPL globules and groundwater in contact with DNAPL) into each segment of the trench (gpd)

$C_{W\text{-}DNAPL}$ = Effective solubility of the contaminant in groundwater for Detrex DNAPL (mg/L). As shown in Table A-1, the effective solubility of each constituent of the DNAPL mixture was determined by multiplying the mole fraction of the constituent in the DNAPL mixture by its pure form solubility limit (Mercer and Cohen, 1990)[1].

C_{gw} = Average contaminant concentration in "clean" groundwater, assumed to be zero mg/L.

V_{gw} = Average flux of "clean" groundwater into each segment of the trench (gpd)

C_{Sump} = Average concentration of the contaminant in sump water (mg/L). For each segment of the trench, we calculated the average concentration of the contaminant using sump water quality data collected by Detrex in September 2007, November 2007, January 2008, and February 2008.

V_{Total} = Average flux recorded at each sump by Detrex (gpd).

[1] Mercer, JW; Cohen, RM. 1990. "Review of immiscible fluids in the subsurface: Properties, models, characterization and remediation." *J. Contam. Hydrol.* 6:107-163.

Given the assumption that the "clean" groundwater does not contain detectable levels of contamination (URS, 2006), *i.e.*, $C_{gw} = 0$, the equation can be revised as follows:

$$V_{W-DNAPL} = \frac{(C_{Sump} \times V_{Total})}{C_{W-DNAPL}}$$

The calculations to determine the flux of DNAPL-groundwater mixture into the three segments of the trench are presented in Table A-2. Note, the calculations were only performed for the four VOCs (tetrachloroethene, trichloroethene, 1,2-dichloroethene and 1,1,2,2-tetrachloroethene) that were detected in sump water samples and are the primary constituents of the Detrex DNAPL mixture.

Table A-1
Effective Solubility Calculations for Detrex DNAPL
Fields Brook Superfund Site, Ashtabula, OH

Compound	Composition of Detrex DNAPL from MW-07S (µg/kg) [1]	Solubility Limit (mg/L)	Molecular Weight (g/mole)	Mole Fraction	Effective Solubility (mg/L) [2]
1,1,2-Trichloroethane	150,000	1100	133.41	0.0003	0.3
1,2-Dichlorobenzene	430,000	80	147	0.001	0.1
Chloroform	680,000	7950	119.4	0.001	10.8
Tetrachloroethylene	45,000,000	206	165.8	0.065	13.3
Trichloroethylene	290,000,000	1280	131.4	0.526	673.3
1,2-Dichloroethylene (total)	1,300,000	3,500	96.94	0.003	11.2
1,1-Dichloroethene	480,000	2,420	96.94	0.001	2.9
1,1,2,2-tetrachloroethane	260,000,000	2,870	167.85	0.369	1059.6
Hexachloroethane	20,000,000	50	236.74	0.020	1.0
Hexachlorobutadiene	8,500,000	3	260.76	0.008	0.0
Hexachlorobenzene	4,600,000	0.006	284.78	0.004	0.0
4-chloro-3-methylphenol	950,000	3,830	142.59	0.002	6.1

Note:

1. de maximis, Inc. 2005. Fields Brook Action Group Report of 2005 DNAPL Investigation, Fields Brook Superfund Site, Ashtabula, Ohio. September 30.
2. Effective Solubility = Solubility Limit x Initial Mole Fraction

Table A-2
Detrex Groundwater Interceptor Trench Calculations
Fields Brook Superfund Site, Ashtabula, OH

Sump #1

Total Flux of DNAPL-groundwater mixture into Segment#1 (Vtotal) = 1250 gpd

Compound	Average Measured Concentration in Sump 1 Water	Effective Solubility in Groundwater	Flux of DNAPL-groundwater mixture into Segment #1	Flux of DNAPL-groundwater mixture into Segment #1
	C_{sump} (mg/L)	$C_{W\text{-}DNAPL}$ (mg/L)	$V_{W\text{-}DNAPL}$ (gpd)[1]	$V_{W\text{-}DNAPL}$ (gallons per year)
Tetrachloroethylene	0.002	13.3	0.210	77
Trichloroethylene	0.003	673.3	0.005	2
1,2-Dichloroethylene (total)	0.000	11.2	0.000	0
1,1,2,2-Tetrachloroethane	0.000	1059.6	0.000	0

Sump #2

Total Flux of DNAPL-groundwater mixture into Segment#2 (Vtotal) = 750 gpd

Compound	Average Measured Concentration in Sump 2 Water	Effective Solubility in Groundwater	Flux of DNAPL-groundwater mixture into Segment #2	Flux of DNAPL-groundwater mixture into Segment #2
	C_{sump} (mg/L)	$C_{W\text{-}DNAPL}$ (mg/L)	$V_{W\text{-}DNAPL}$ (gpd)[1]	$V_{W\text{-}DNAPL}$ (gallons per year)
Tetrachloroethylene	0.007	13.3	0.405	148
Trichloroethylene	0.034	673.3	0.038	14
1,2-Dichloroethylene (total)	0.110	11.2	7.349	2682
1,1,2,2-Tetrachloroethane	0.001	1059.6	0.001	0.3

Sump #3

Total Flux of DNAPL-groundwater mixture into Segment#3 (Vtotal) = 200 gpd

Compound	Average Measured Concentration in Sump 3 Water	Effective Solubility in Groundwater	Flux of DNAPL-groundwater mixture into Segment #3	Flux of DNAPL-groundwater mixture into Segment #3
	C_{sump} (mg/L)	$C_{W\text{-}DNAPL}$ (mg/L)	$V_{W\text{-}DNAPL}$ (gpd)[1]	$V_{W\text{-}DNAPL}$ (gallons per year)
Tetrachloroethylene	0.001	13.3	0.009	3
Trichloroethylene	0.001	673.3	0.0002	0.1
1,2-Dichloroethylene (total)	0.000	11.2	0.0000	0
1,1,2,2-Tetrachloroethane	0.000	1059.6	0.000	0

Note:

1) $V_{W\text{-}DNAPL} = (C_{sump} * V_{total})/C_{W\text{-}DNAPL}$